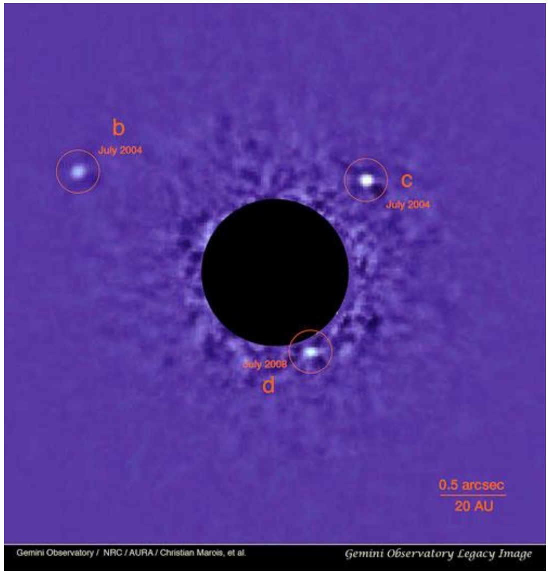
Predictive thermal control applied to HabEx

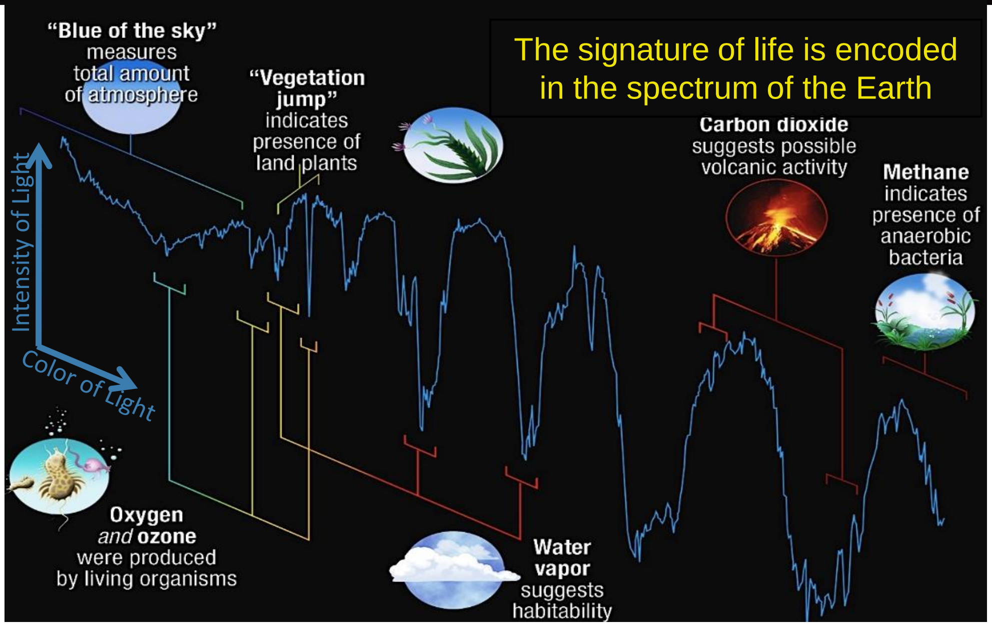
Thomas Brooks
Marshall Space Flight Center
256.797.3147

HabEx Brief Background

Science Objectives

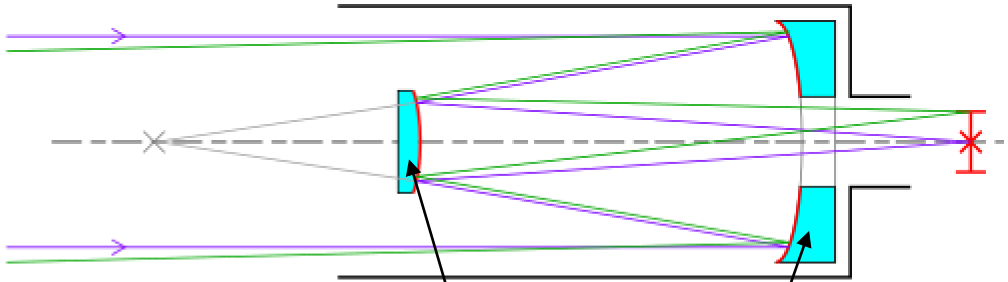


Example of exopolanets imaged with a ground based system.[1]



Biosignatures.[2]

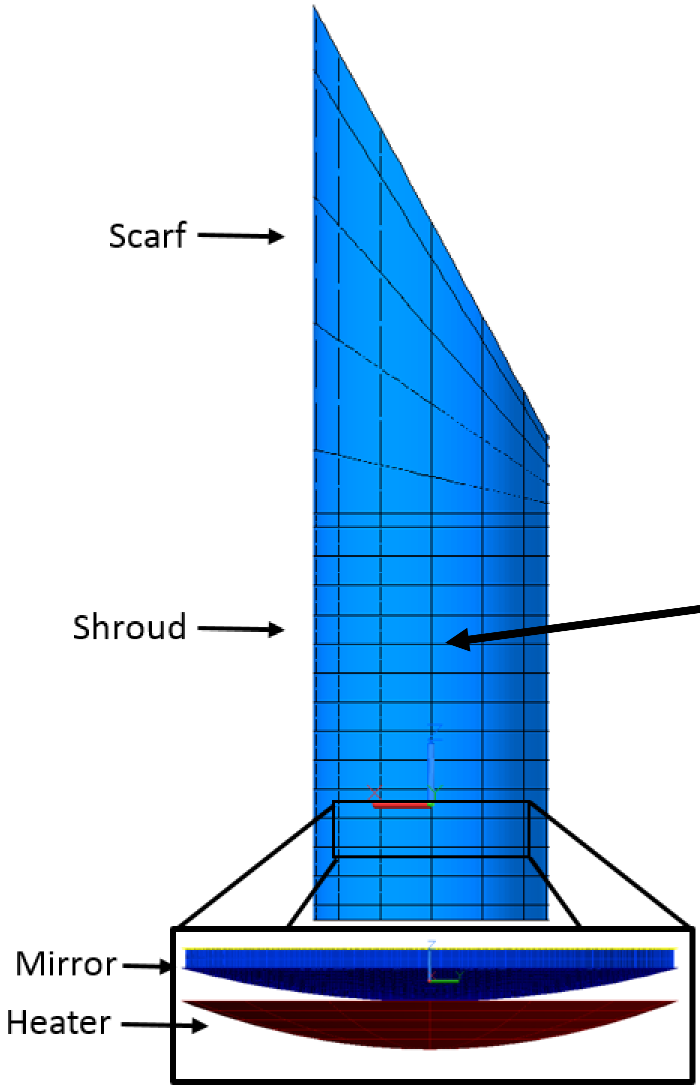
Engineering Requirements

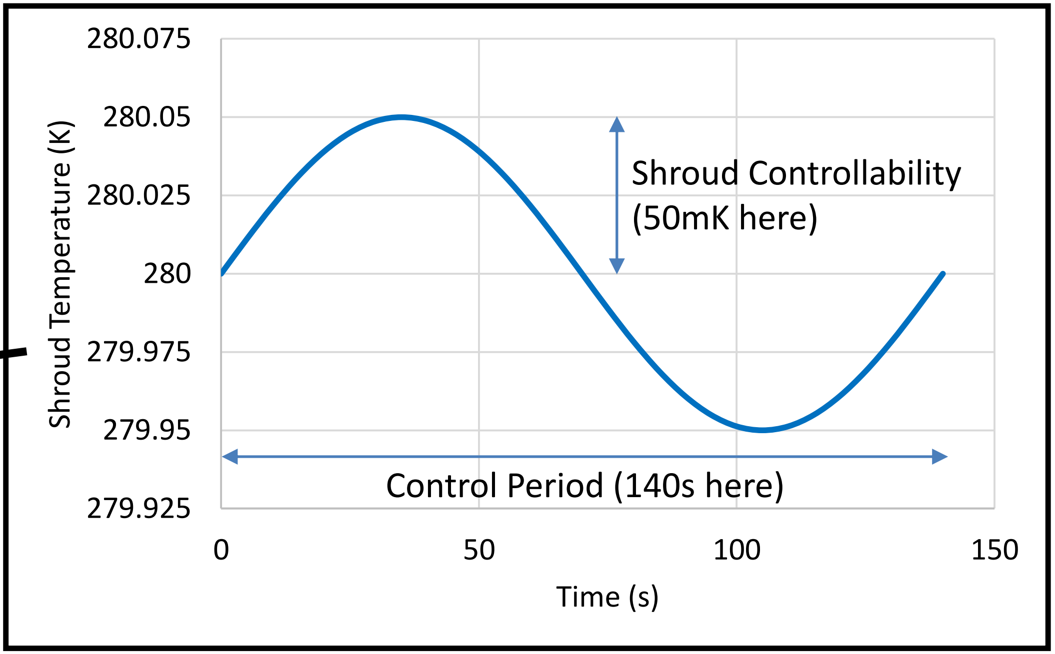


SFE may not change by more than 10pm in 10 minutes

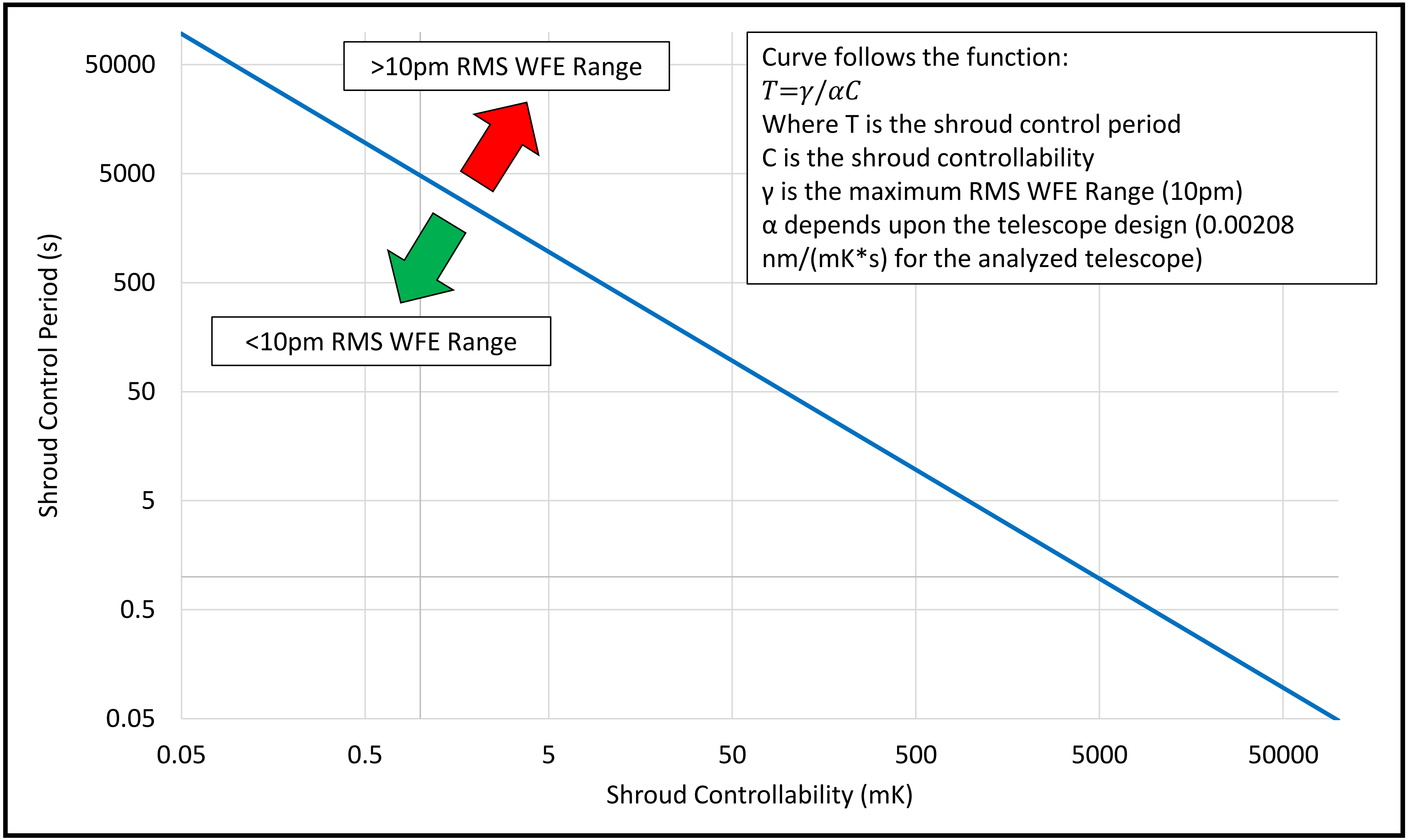
Position may not move by more than ~2nm per 10 minutes

Thermal Analysis Approach





Thermal Stability Requirement



1-D Rod Closed-Form Model

Rod with a mass, specific heat, thermal energy, temperature and coefficient of thermal expansion of m, c_p, Q, T, and CTE respectfully

Length of rod, L

- Equation 1 describes heat storage in the rod
- Equation 3 describes linear thermal expansion
- Algebra and calculus then Equation 5
- Equation 5 shows variables that affect thermal strain rate
  - Geometry dependent: L, V, dQ/dt (surface area)
  - Material dependent: CTE, ρ, c_p, and dQ/dt (emissivity and absorptivity)

$$Q = \rho V c_p T \qquad \text{Equation 1}$$

$$\frac{dQ}{dt} = \rho V c_p \frac{dT}{dt} \qquad \text{Equation 2}$$

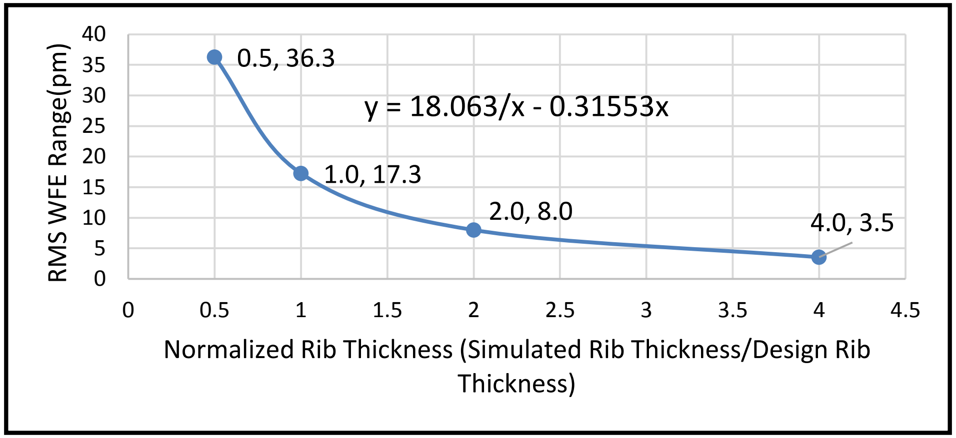
$$(\mathrm{CTE}) L \Delta T = \Delta L \qquad \text{Equation 3}$$

$$\frac{dT}{dt} (\mathrm{CTE}) L = \frac{dL}{dt} \qquad \text{Equation 4}$$

$$\frac{dL}{dt} = \frac{(\mathrm{CTE}) L}{\rho V c_p} \frac{dQ}{dt} \qquad \text{Equation 5}$$

Passive Design Figures of Merit

- Numerical and analytical models agree that heat capacity and CTE have very strong affects on thermal deformation rates.



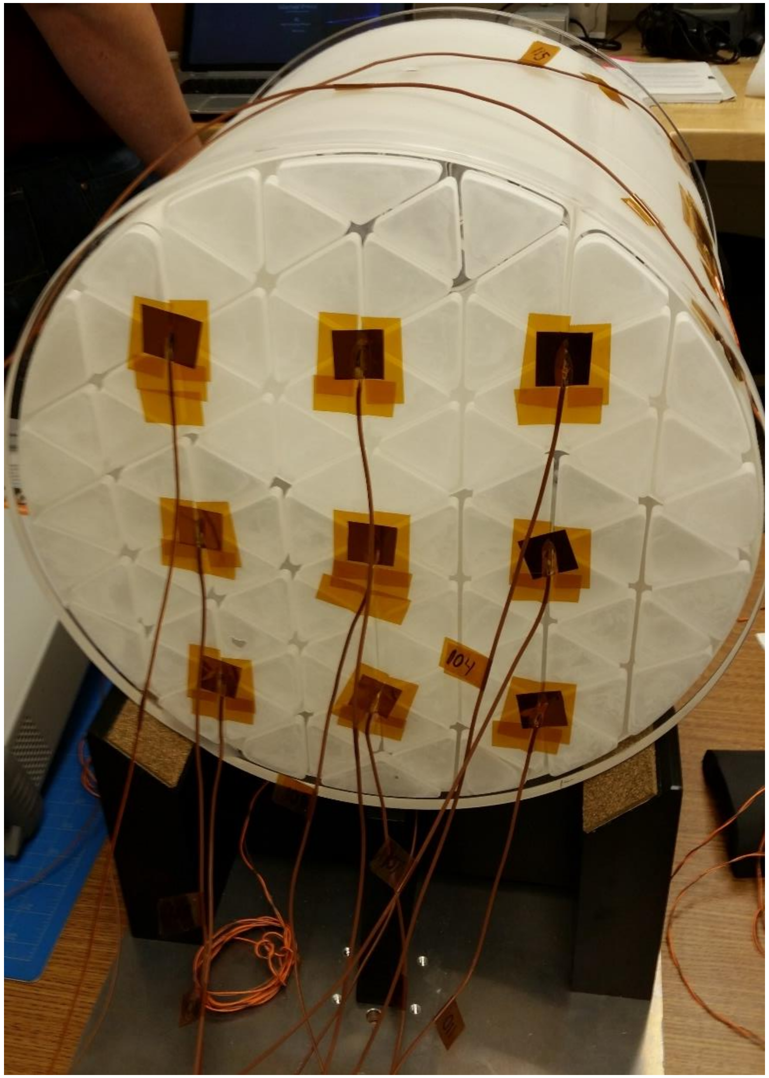
$$\frac{dL}{dt} = \frac{(\mathrm{CTE})L}{\rho V c_p}\frac{dQ}{dt}$$

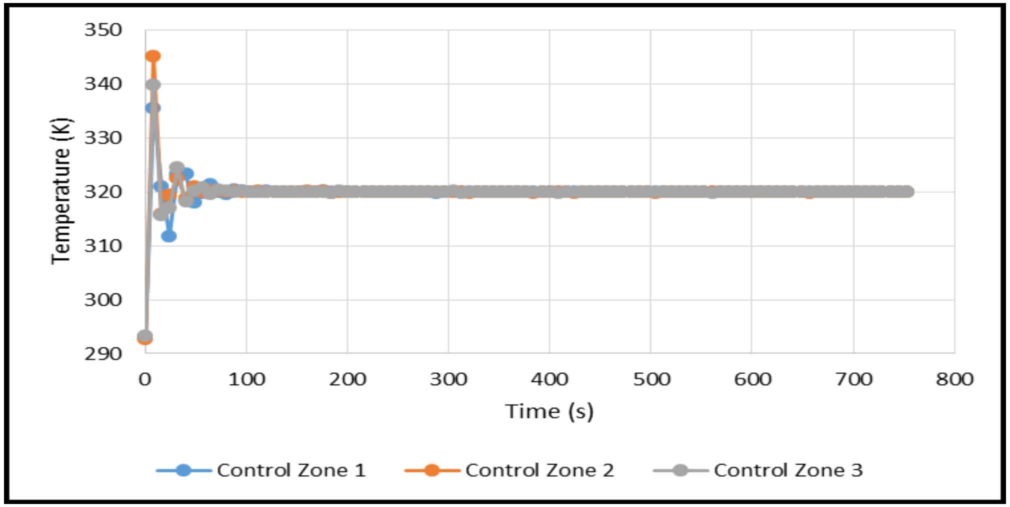
- For an actively controlled substrate, the following figures of merit are proposed:

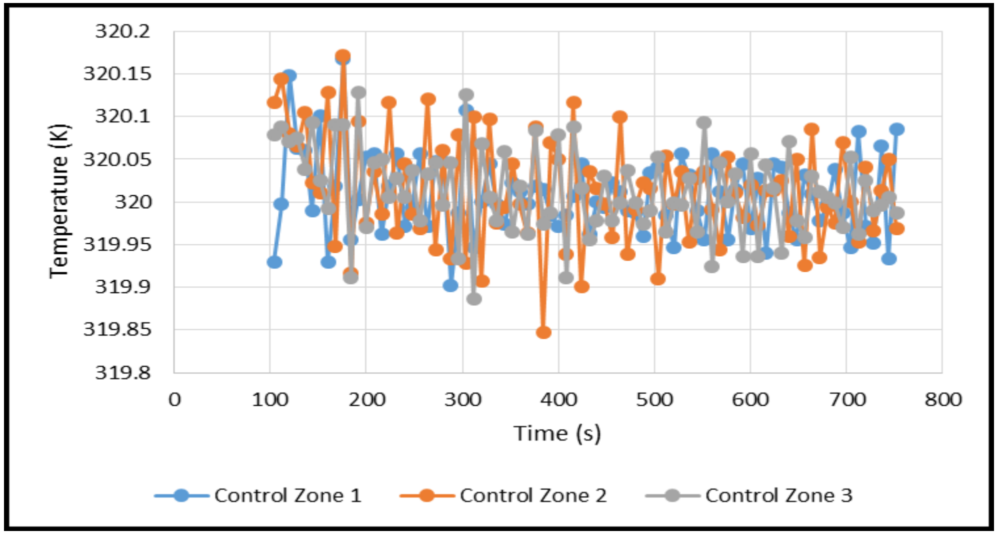
$$\text{Massive Active Optothermal Stability, MAOS} = \frac{\rho c_p}{CTE}$$

$$\text{Active Optothermal Stability, AOS} = \frac{c_p}{CTE}$$

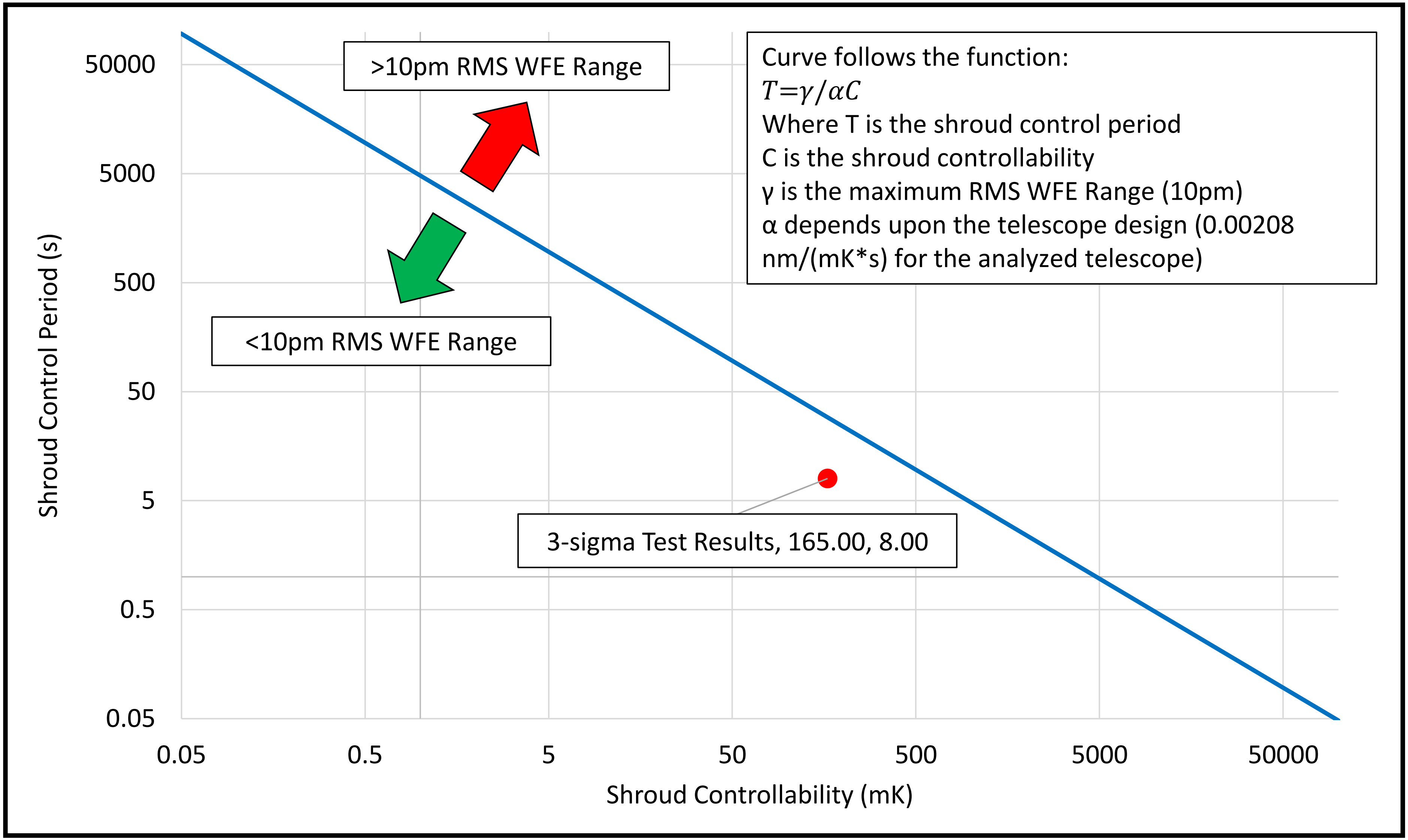
Subscale Test







Test Compared to Requirement



Questions or Comments?

Contact Information

Thomas Brooks

Thomas.brooks@nasa.gov

Work - (256) 544 -5596

Cell - (256) 544 -5596